STRATUS CONSULTING

Technical Review of the Draft Water Management Plan for the Chuitna Coal Project, Alaska

Prepared for:

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Executive Summary

As currently written, the water management plan for the proposed Chuitna coal mine is based on a scientific record that contains too many uncertainties to guide water management decisions for an operating coal mine. As a result, if the mine were developed under this plan, both the quality and quantity of water requiring management could be substantially different from what is anticipated. The key issues that we identified are as follows:

Water balance

1. The water balance was developed using non-standard methods. Most importantly, it back-calculates precipitation from the other water balance components, rather than using measured precipitation data collected onsite. A mine that has been under consideration for development for more than two decades should have a site-specific record on which to base its site water balance.

2. The remaining components of the site water balance each have uncertainties that are not adequately characterized. For example, evapotranspiration is estimated using data from a station more than 100 km away from the site. Baseflow throughout the mine area is estimated from streamflow at a single gage station on the Chuit River (C180), but the poor correlation between streamflow at this gage and the other onsite gages introduces a number of additional uncertainties into the site water balance.

3. The sizing of the sediment control ponds is not based on a realistic wet year scenario and does not take climate change into account. As a result, it is highly likely that the control ponds, as currently designed, will overflow multiple times during mine operation.

4. There is no discussion of how these varied uncertainties could influence water management plans into the future. At a minimum, the plan should quantify the uncertainties in the water quality and quantity requiring management and outline specific steps that will be taken to adapt if actual outcomes deviate significantly from expectations.

5. Recommendations

    a. The water balance needs to be recalculated using site-specific precipitation and evaporation data and should include an evaluation of the effects of climate change on precipitation, evaporation, and streamflow.

    b. The sediment control ponds should be redesigned using a more realistic wet year scenario that reflects observed site data and takes climate change into account. The potential effects of overflow on water quality should be evaluated.

   c. A set of diagrams should be created that shows the water volumes from all sources under expected high- and low-flow conditions, along with associated uncertainties.

Groundwater model

1. There is significant uncertainty about the source of recharge to the Sub Red 1 Sand unit and the conceptualization of the unit and its hydrologic properties in the model. Because of its importance in the water balance (approximately 50% of the water to be managed derives from the unit, depending on the year of mining), an improved understanding of the amount of recharge to the Sub Red 1 Sand unit is needed to understand the total volume of water that could require management during mining.

2. The groundwater pumping and pit inflow rates are presented as single values in the water management plan, which implies that there is no uncertainty surrounding those numbers. The plan does not but should discuss the degree of uncertainty associated with the values.

3. To the best of our knowledge, no aquifer testing of the faults, including the large Chuit Fault, has been conducted. Given the importance of faults as potential conduits for or barriers to groundwater flow, more characterization of this and other faults on the site is needed.

4. Recommendations

   a. A quantitative evaluation of the uncertainties associated with recharge to the Sub Red 1 Sand unit and groundwater pumping and pit inflow rates should be conducted. The model domain should be expanded to account for potential recharge from outcrop and subcrop areas of the Sub Red 1 Sand unit, and to ensure that modeled drawdown is not affected by model boundary conditions.

   b. An analysis of the uncertainty in predicted pumped volumes should be conducted.

   c. The groundwater model should be rerun using site-specific precipitation and evaporation data, improved estimates of recharge to the Sub Red 1 Sand unit, and other recommendations discussed in Section 2.2.

Water quality

1. The temporal variability in baseline water quality is not well characterized, especially for surface water on timeframes that evaluate hydrologic events such as ice breakup, snowmelt, and fall rains.

2. The evaluation of water quality exceedences finds that baseline conditions are not meeting water quality criteria and standards at the site for a number of constituents. However, uncertainties related to detection limits and hardness values, which are quite low in surface water and higher in groundwater, were not considered, and State of Alaska recommendations for using the criteria were not always followed.

3. Essentially no information is provided on the geochemical characteristics of the mined materials and how excavation and handling of the materials could affect water quality during and after mining.

4. The temporal variability in baseline water quality is not well characterized, especially for surface water on timeframes that evaluate hydrologic events such as ice breakup, snowmelt, and fall rains.

5. Recommendations

   a. Exceedences of water quality criteria should be re-evaluated, taking into account applicable State of Alaska regulations, uncertainties regarding detection limits, and temporal variability in water quality, including hardness and dissolved metal concentrations.

   b. Mineralogic and whole rock chemistry analysis of all mined materials should be conducted. Short- and longer-term leach testing of all mined materials should also be conducted to evaluate the potential for oxidization of remnant sulfides and the generation of metal-rich leachate. The results of these geochemical tests should be used to inform predictions of operational and post-mining water quality.

   c. Because of the large uncertainties associated with metal toxicity at low hardness values, the existence of anadromous fish, and the presence of metals such as copper and zinc, site-specific fish toxicity testing should be seriously considered to help understand the potential effects of mining on native fish populations.

1. Introduction

The Chuitna Coal Project is a proposed surface coal mine in south central Alaska located west of Anchorage and on the western side of Cook Inlet (Figure 1). The coal reserve is owned by PacRim; mining the reserve would disturb approximately 5,000 acres over a 25-year mine life, producing approximately 300 million metric tons of coal. Surface mining would extract coal from several pits that would be backfilled as mining progresses. Mining would remove portions of streams in the project area, including the 2003 stream (also known as Middle Creek; see Figure 1). Restoration of the 2003 stream channel is proposed (Tetra Tech, 2013). The Native American Rights Fund (NARF) requested that Stratus Consulting review hydrologic, hydrogeologic, and water quality issues associated with the management of water at the site if the mine is approved.

This report summarizes our technical review of the *Revised Draft Water Management Plan, Chuitna Coal Project* (water management plan, or Tetra Tech, 2013). Our review focuses on the methods used to develop the water management plan, as well as the completeness and quality of data used to support the plan. Over the course of our review, we also evaluated the *Chuitna Coal Project Hydrology Component Baseline Report* (RTI, 2007), the *Chuitna Coal Project Groundwater Baseline Report – Draft* (RTI, 2010), and some aspects of the groundwater modeling work summarized in the *Chuitna Coal Project Groundwater Model Report* (Arcadis, 2013), because the results of these studies are key to interpretation of site water management.

In Section 2, we summarize our general comments on three topic areas related to the water management plan and associated documents:

- Hydrology and water balance
- Groundwater model
- Water quality.

We list specific comments on sections of the water management plan related to hydrologic conditions in Section 3.

2. General Comments

2.1 Hydrology and Water Balance

The development of a water management plan requires the compilation of adequate data to estimate precipitation, evapotranspiration, groundwater recharge, and streamflow over the life of the proposed mine. The site water balance therefore underlies all of the decisions outlined in the

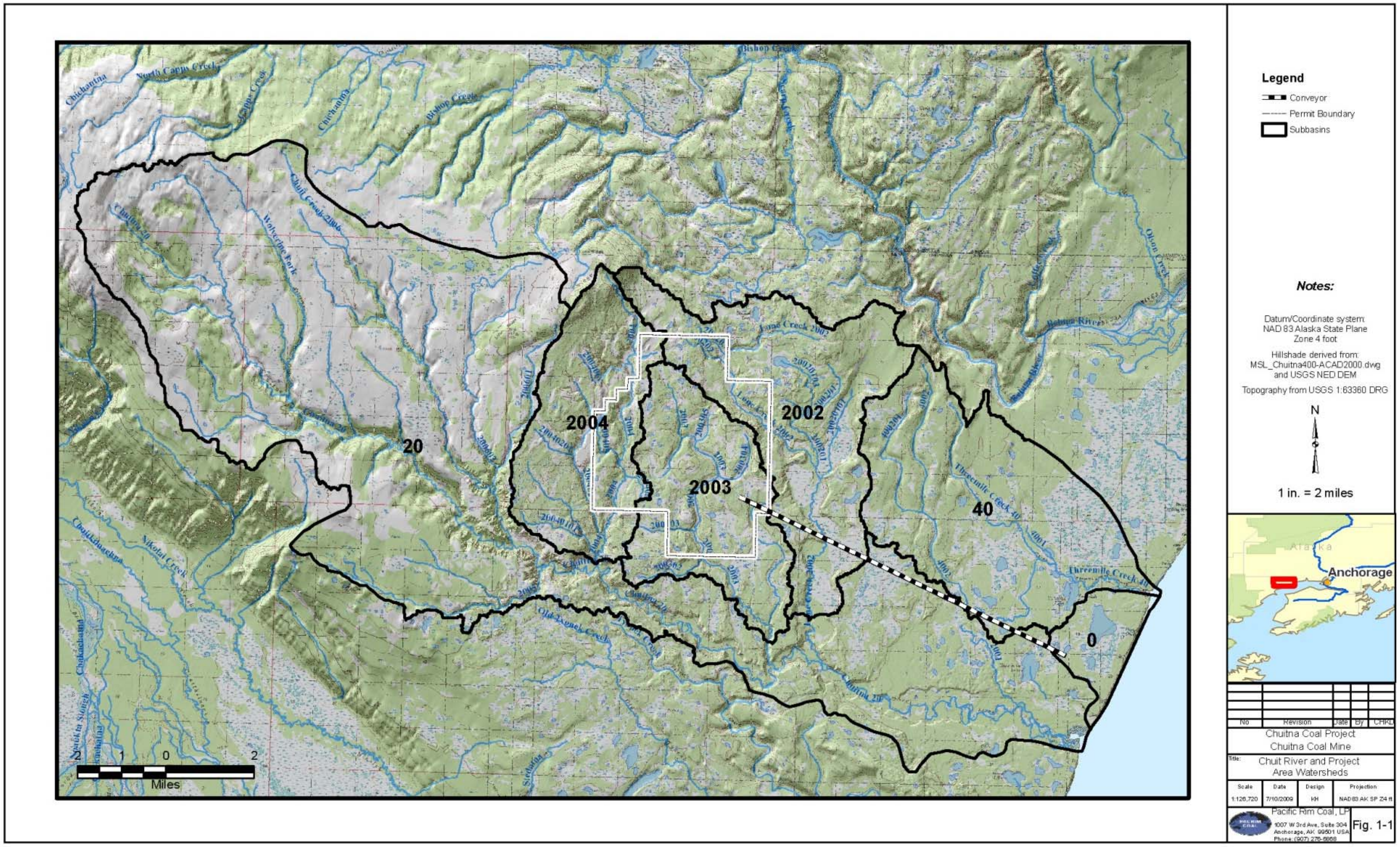

Figure 1. Approximate location of proposed Chuitna Coal Project.

Source: Tetra Tech, 2013, Figure 1-1.

water management plan and requires particular scrutiny. In addition, the design of infrastructure to manage future flows relies on an estimate of future flow rates that might be expected over the mine lifetime. We identified a number of issues with the site water balance and the estimates of future flow rates, as described in detail below.

In addition to the detailed issues below, we note that most water management plans include diagrams that show the amounts and sources of water requiring management, yet none are included in revised draft plan (Tetra Tech, 2013). Diagrams should be included in the final plan that illustrate the uncertainties and potential ranges of flow volumes, including volumes expected under low-flow and high-flow conditions.

2.1.1 Site water balance uncertainties

The water balance as currently described lacks sufficient observational data to be reliable. One of the most important inputs to a site water balance is the total precipitation falling on the site, because this value ultimately controls the total amount of water that will need to be managed. Rather than using measured precipitation for the site water balance, the current plan is based on a precipitation value that is back-calculated from the other components of the water balance:

> Long-term stream flow (measured on-site) and evaporation data (from the Matanuska station, with modifications discussed below) were available, and groundwater recharge and base flow were estimated using a calibrated groundwater model (Arcadis, 2012). Precipitation was then determined by subtraction. (Tetra Tech, 2013, p. 4)

Based on the more detailed descriptions of the water balance contained in the water management plan, the only measured, site-specific parameter consistently used in the water balance is the streamflow at station C180 on the Chuit River. Streamflow at all other sites, as well as precipitation, evaporation, and groundwater flow, are either correlated to this record, modeled, or measured at remote sites. This is a very circuitous approach to calculating a site water balance and has the potential to introduce substantial errors into the water budget. For example, pan evaporation data are from Matanuska station, more than 100 km away from the site. Recharge and baseflow values rely on a groundwater model that also has substantial uncertainties (see Section 2.2).

The net result of these issues is that the overall water balance is likely to have a very high degree of uncertainty, which is not well characterized in the current draft of the water management plan. These uncertainties should be explicitly addressed in the report, along with specific descriptions of how water management decisions will be adapted if key components of the water balance (such as precipitation) differ from expectations.

2.1.2 Design storm used for mine infrastructure

The sediment control ponds appear to be the primary line of defense for protecting downstream water quality. The goal of these ponds is to allow particulates and their associated contaminants to settle out of the water column before discharging to downstream waters. However, based on the description in the water management plan, the design storm used for sizing these water management structures is too small to prevent overflows:

> The "wet" year scenario was developed to provide a conservative design volume for handling long-duration high spring runoff flows during above-average years, without encroaching in to the 10-year, 24-hour storm capacity of the ponds. The scenario was developed using monthly stream flows of 15% of one standard deviation above the station C180 mean for the critical spring runoff months of April, May, and June, and 10% of a standard deviation above the mean for the remaining months. (Tetra Tech, 2013, p. 7)

Water control structures such as sediment ponds should be designed to accommodate rare high-flow events. Even assuming a stationary climate (i.e., assuming no future climate change), a 10-year, 24-hour event is almost certain to be exceeded multiple times over a mine life of 25 years. Tetra Tech estimated a "wet" year for control pond design by adding only 15% of one standard deviation to the mean flow at station C180. This approach will not protect areas surrounding the control ponds from overflow during mine operation. For example, based on flow statistics from the 17 complete years of monitoring reported for station C180 (RTI, 2007), a wet year using the Tetra Tech (2013) design scenario would have only 10–20% more flow from April to June than an average year, whereas the *observed* monthly average streamflows over this period have been over 400% larger than the mean flow. Natural variability in streamflow will create wet and dry years that are well outside the envelope of variability estimated from these calculations. This could become an even larger problem if climate change is considered and high flows become more severe and/or more frequent. However, climate change was not considered at all when designing the sediment control ponds.

The assumptions used in designing the sediment control ponds therefore strongly suggest that the capacity of the ponds will be exceeded multiple times over the mine lifetime. Because the purpose of the sediment control ponds is to improve discharge water quality by removing particulates from the water column, it would be preferable to see a stormwater pond design that is more likely to withstand all storm events anticipated over the mine lifetime. If this is not the case, the water management plan needs to acknowledge that stormwater pond overflows will occur and should include more discussion of the water quality implications of these overflows.

2.1.3 Adaptive management

Given the number and potential magnitude of uncertainties introduced from the water balance approach, it is likely that the actual water management outcomes will be different from what is predicted in the water management plan. An adaptive management plan should therefore be developed that demonstrates that contingencies have been adequately considered, and that there are options for managing mine water if the water balance proves to be incorrect. As currently written, the report simply states that the water balance and water management plan will be reevaluated every 2.5 years [as required under the Alaska Surface Coal Mining and Reclamation Act (ASCMCRA)].

At a minimum, the water management plan would benefit from a more detailed discussion of what targets will be evaluated under an adaptive management plan (e.g., streamflows, stream temperatures, water quality parameters, managed water volumes) and how specific components of the plan will be adjusted if these targets are not met. This would ensure that sufficient advanced planning has occurred to prepare engineering solutions for a range of potential water management issues.

2.2 Groundwater Model

We conducted a limited review of specific details of the groundwater model related to the Sub Red 1 Sand unit, including recharge and depressurizing, and we have provided some more general comments related to model domain, sensitivity analyses, and treatment of faults in the model.

The volume of water that will need to be managed as described in the water management plan is predicted using a groundwater flow model prepared by Arcadis (2013). The ability of the groundwater model to predict the amount of water to be managed and the potential impacts on baseflow in streams is dependent on a good representation of the meteorological inputs, including precipitation, and surface processes such as evapotranspiration, runoff, and recharge to groundwater. Reliable predictions also rely on a realistic conceptual model of the hydrogeologic units and structures and their properties, as well as model boundary conditions that reflect the actual conditions present in the subsurface.

2.2.1 Uncertainties related to recharge to the Sub Red 1 Sand unit

Model-predicted pumping from the Sub Red 1 Sand unit ranges from 1.24 cfs in the first year to a peak of 6.57 cfs in year 7. For many of the years, the model estimates that water pumped from the Sub Red 1 Sand unit represents 50% or more of the water to be pumped and managed. Thus for the water management plan, it is important that the model accurately represent groundwater conditions, including recharge, within the Sub Red 1 Sand unit. However, there is significant uncertainty about the source of recharge to the Sub Red 1 Sand unit and whether this unit is well represented by the model.

Recharge to the Sub Red 1 Sand unit could come from infiltration from overlying units or direct recharge where the unit subcrops or outcrops. The Mineable Coal Sequence in the calibrated model has extremely low vertical hydraulic conductivity, ranging from 10^{-4} ft/day in the interburden to 10^{-7} ft/day in some areas. The model input values are on the low end of the literature-reported range of hydraulic conductivity values for any geologic material, including relatively unfractured crystalline rocks (e.g., Freeze and Cherry, 1979). Using such extremely low vertical hydraulic conductivities will greatly impede any modeled vertical migration of water and recharge to underlying units. Given these low values, the Sub Red 1 Sand unit in the model is unlikely to be recharged significantly from overlying units.

The Sub Red 1 Sand may also obtain recharge from areas where it outcrops or subcrops at or near the ground surface, receiving recharge directly from the land surface or overlying high-permeability alluvial units. In the model, however, it appears that any subcropping or outcropping locations are outside of the model domain. Based on geologic cross-sections contained in RTI (2007), as well as cross-sections such as T-T' and U-U' in Arcadis (2013), it appears that the Lower Mineable Coal Sequence and the Sub Red 1 Sand unit are closer to the land surface and occur at higher elevations in the northern portion of the site. The lowest mineable coal seam, Red 1 Coal, located just above the Sub Red 1 Sand unit, subcrops to the north of the site (Arcadis, 2013, Appendix B, Figure 5), suggesting that the Sub Red 1 Sand unit is very close to the surface in this area. Although the Sub Red 1 Sand unit is closer to the surface in the northern portion of the model domain, geologic cross-sections and maps indicate that it does not outcrop or subcrop within the model domain.

If the Sub Red 1 Sand unit receives significant recharge outside of the model domain to the north, where it may subcrop or outcrop, this recharge is not simulated by the model. Thus long-term flows from the Sub Red 1 Sand unit could be underestimated. The northern model boundary of the Sub Red 1 Sand unit is a "no flow" boundary, which means that flow will not be simulated to enter the unit from the north. Groundwater levels indicate that there may be recharge to the Sub Red 1 Sand unit to the north of the site. The potentiometric surface in well 14S, which is completed in the Sub Red 1 Sand unit in the north portion of the site, is 671 ft (Arcadis, 2013, Appendix B, Figure 6), which is significantly higher than the potentiometric surface in well 23U (547.3 ft) to the south. The measured differences in head suggest that groundwater flows from north to south in this area.

The western model boundary for the Sub Red 1 Sand unit is specified as a general head boundary condition. This will allow simulated flow to enter the Sub Red 1 Sand unit from outside the model domain. Any flow entering the model from this boundary then would need to cross the Chuit Fault to provide recharge to the mine area. It does not appear that there has been aquifer testing across or along the fault to provide an understanding of the hydrologic behavior of this fault and how it influences groundwater flow.

Nevertheless, the Chuit Fault is simulated in the model using a very low hydraulic conductivity of 10^{-5} ft/day (Arcadis, 2013). In the model, this low hydraulic conductivity would allow very little flow from west to east across the fault. Given the potential importance of faults as conduits for movement of groundwater, pumping tests should be conducted in the field to understand the hydrologic behavior of the faults. Furthermore, given the lack of field data, the uncertainty in the predicted Sub Red 1 Sand unit pumping rates to the simulated Chuit Fault should be evaluated in the model uncertainty analysis.

2.2.2 Assumptions about recharge to the lower groundwater system

The groundwater model report text, Appendix B of the modeling report (Arcadis, 2013), and the hydrology baseline data reports (RTI, 2007, 2010) contain inconsistent assumptions about precipitation and recharge to the lower groundwater system (i.e., below the Glacial Drift formation). The estimated annual precipitation used in the groundwater model is 47 in/yr on average (ranging from 44 to 50 inches). This is 3 in/yr more than the average estimate of 44 in/yr reported in RTI (2007), so it is not clear where the 47 in/yr estimate comes from. Of the 47 in/yr used in the groundwater model, approximately 12 in/yr (or 27%) is assumed to become groundwater recharge, and 2.8% (0.3 in/yr) recharges the lower groundwater system, defined as the units below the Glacial Drift [including the Mineable Coal Sequence and the Sub Red 1 Sand unit (Arcadis, 2013)]. This amount is not consistent with the value in Appendix B of the model report that estimated, based on Darcy's Law, that 9% of the total groundwater recharge, or 1.1 in/yr, enters the Mineable Coal Sequence.

Furthermore, the model report does not specify how much of the recharge to the "lower groundwater system" recharges the Sub Red 1 Sand unit. As described above, an improved understanding of the amount of recharge to Sub Red 1 Sand unit is needed to understand the total volume of water that requires management during mining.

2.2.3 Missing sensitivity analyses

The sensitivity analyses that were conducted with the model evaluated the impact of model changes on stream baseflow. These analyses did not evaluate the model sensitivity to other predictions, such as the amount of water to be pumped and managed in the Lower Mineable Coal

Sequence and the Sub Red 1 Sand unit. A sensitivity analysis evaluating changes in predicted volumes to be pumped would provide some insight into the range of uncertainty in the projected pumping volumes. The pumping rates and pit inflow rates in the water management plan are presented as single values. The final water management plan should include a discussion of the uncertainty in these values.

2.2.4 Model boundary conditions

The general head boundary conditions may be influencing the predicted volume of water to be managed, because the simulated drawdown cone intersects the model boundary in two of its lower layers. Model boundary conditions control how groundwater enters and leaves the flow system. In the model, layers that represent the Lower Mineable Coal Sequence and the Sub Red 1 Sand unit have “no flow” (i.e., no flux) boundaries on the north side, and general head boundary conditions on the west, south, and east sides.

The simulated drawdown extends to the west, south, and east “general head” model boundaries in the Lower Mineable Coal Sequence and the Sub Red 1 Sand unit (Arcadis, 2013, Figures 63c and 63d). In general, model boundaries should be located far enough from model stresses that the boundaries placed on the model cannot influence the model results. In short, the model domain should be expanded. Because the simulated drawdown reaches the model boundary, the conditions set on this general head boundary (i.e., conductance and head conditions) will affect the model predictions. The model sensitivity analysis should evaluate the influence of the general head boundary conditions on the amount of water that would need to be pumped from the Lower Mineable Coal Sequence and the Sub Red 1 Sand unit.

2.2.5 Simulation of dewatering and depressurizing

The groundwater model report should provide more information on the methods used to simulate dewatering and depressurization over time.

According to Tetra Tech (2013), the mine life is 25 years. The figures showing the well locations (i.e., Figures 39 through 41 in Arcadis, 2013) show well locations only for the first eight years of mine life. For example, Figures 41a through 41i (Arcadis, 2013) show the locations of proposed depressurization wells in the Sub Red 1 Sand unit from year 1 through year 8, and the layout of these proposed wells changes nearly every year. However, no information is provided in the groundwater modeling report about the location of proposed depressurization wells from years 9 through 25, and it is unclear whether dewatering/depressurization will occur using the same wells, or whether additional wells will be installed. There is also no information on how much water is simulated in the model as being pumped by each of the wells over time. Based on Table 2-7 of the water management plan (Tetra Tech, 2013), pumping will occur in the

Sub Red 1 Sand unit throughout the 25-year mine life. The results for simulated pumping should be provided in the model report to facilitate model review.

2.3 Water Quality

The water management plan briefly discusses water quality issues in Section 5.0, APDES Outfalls (Tetra Tech, 2013). Water quality is discussed in more detail in Section 6 of the *Chuitna Coal Project Hydrology Component Baseline Report*, Chemistry of Surface Water and Groundwater (RTI, 2007), and in Section 5 of the *Chuitna Coal Project Groundwater Baseline Report – Draft* (RTI, 2010). The primary issues regarding water quality are assumptions made about baseline water quality conditions in surface water and groundwater, geochemical characterization and implications for mine water quality and mitigation measures, and uncertainties about water quality after mining and stream restoration.

2.3.1 Baseline surface water quality and site-specific water quality criteria

The operation of the coal project would include two sources of mine water discharge to state surface waters: one from sediment control ponds and another from pumped groundwater. PacRim Coal has presented information showing that concentrations of certain metals in surface water and groundwater exceed Alaska water quality criteria under current (pre-mining, or baseline) conditions. Alaska water quality criteria apply equally to surface water and groundwater (RTI, 2007), and measured values in the waters were compared to the most stringent water quality criteria (RTI, 2007, 2010; Tetra Tech, 2013). Based on a series of assumptions about baseline water quality and relevant standards, PacRim Coal is planning to apply for site-specific water quality criteria for aluminum, manganese, copper, and zinc (Tetra Tech, 2013). Site-specific water quality criteria would serve to increase allowable concentrations of these constituents in mine-related discharges to streams. Discharge outfall locations would be in the 2003 drainage for the most part, as well as in the 2002 and 2004 drainages and potentially in Cook Inlet (see Figure 1).

The relevant water quality standards and criteria for a water body are a function of the designated uses established by the State of Alaska. The designated uses for all Alaskan freshwaters are drinking water; aquaculture; growth and propagation of fish, shellfish, other aquatic life, and wildlife; industrial; agriculture; and contact and non-contact recreation (RTI, 2007, Table 6-1). Each designated use has its own set of water quality standards or criteria. Tetra Tech (2013) uses the most stringent criteria to compare to baseline stream water concentrations (Table 1), apparently to try to emphasize that baseline water quality exceeds water quality standards. However, we have identified issues with their analysis of baseline water quality data:

Table 1. Examples of copper, lead, and zinc measurements noted as exceedences in Tetra Tech (2013), Tables 5.1 and 5.2, and associated issues

Drainage or formation	Sample date	Analyte	Measured concentration (µg/L)	Criterion used in RTI (2007) (µg/L)[a]	Measured hardness (mg/L as $CaCO_3$)	Issues
2003	12/4/1982	Cu – total	80	2.85	23	AK criterion is for diss Cu; diss Cu is < 20 µg/L (DL > CCC)
		Zn – total	50	37.02	23	AK criterion is for diss Zn; diss Zn is < 20 µg/L (DL > CCC)
	8/15/1991	Cu – total	20	2.85	ND	Hardness not measured; AK criterion is for diss Cu; diss Cu < 10 µg/L (DL > CCC)
		Zn – total	80	37.02	ND	Hardness not measured; AK criterion is for diss Zn; diss Zn < 10 µg/L (DL > CCC)
	11/13/1991	Cu – total	10	2.85	ND	Hardness not measured; AK criterion is for diss Cu; diss Cu < 10 µg/L (DL > CCC)
		Zn – total	50	37.02	ND	Hardness not measured; AK criterion is for diss Zn; diss Zn < 10 µg/L (DL > CCC)
	3/17/1992	Cu – total	20	2.85	ND	Hardness not measured; AK criterion is for diss Cu; diss Cu = 10 µg/L (at DL)
	11/12/1992	Cu – total	20	2.85	ND	Hardness not measured; AK criterion is for diss Cu; diss Cu < 10 µg/L (DL > CCC)
	3/15/1993	Cu – total	10	2.85	ND	Hardness not measured; AK criterion is for diss Cu; diss Cu = 10 µg/L (at DL)
	5/11/2008	Zn – total	40	37.02	< 10	AK criterion is for diss Zn; diss Zn is < 5 µg/L and does not exceed diss Zn CCC (36.5 µg/L)
Sub Red 1 Sand	7/1/2010	Pb – diss	0.5	0.54	80	Did not use measured hardness – at 80 mg/L hardness, dissolved CCC = 2 µg/L and measured value does not exceed it

Table 1. Examples of copper, lead, and zinc measurements noted as exceedences in Tetra Tech (2013), Tables 5.1 and 5.2, and associated issues (cont.)

Drainage or formation	Sample date	Analyte	Measured concentration (µg/L)	Criterion used in RTI (2007) (µg/L)[a]	Measured hardness (mg/L as $CaCO_3$)	Issues
Glacial Drift	8/21/2006	Zn – diss	37	36.5	60	Did not use measured hardness – at 60 mg/L hardness, dissolved CCC = 77 µg/L and measured value does not exceed it
	2/22/2007	Zn – diss	44	36.5	50	Did not use measured hardness – at 50 mg/L hardness, dissolved CCC = 66 µg/L and measured value does not exceed it
	5/23/2007	Cu – diss	4	2.74	50	Did not use measured hardness – at 50 mg/L hardness, dissolved CCC = 5 µg/L and measured value does not exceed it
	5/1/2010	Pb – total	1.4	0.54	80	Did not use measured hardness – at 80 mg/L hardness, total CCC = 2.4 µg/L and measured value does not exceed it

AK = Alaska; CCC = criterion continuous concentration; diss = dissolved; DL = detection limit; µg/L = microgram per liter; ND = analyte not determined.

a. Criteria are listed in Table 6-4; no criteria are listed in Tetra Tech (2013).

- For most metals, the most stringent standard is the dissolved criterion continuous concentration (CCC), or chronic value, which is based on a four-day averaging period, or the average concentration of the analyte over a four-day period (State of Alaska, 2008). It appears that the measured baseline concentrations in Tetra Tech (2013) and RTI (2007) are instantaneous rather than four-day average concentrations.

- Sampling of surface water was limited temporally. For example, for the 2003 drainage (Tetra Tech, 2013, Table 5-1), which seems to have the most extensive water quality data, samples were collected on a quarterly basis (or less). No samples were collected during the month of April, and no recent samples (2004–2010) were collected in April, June, November, or December. Therefore, the temporal variability in baseline water quality is not well known. Knowledge of the range in metals, dissolved organic carbon, and major ion concentrations is especially important for surface water sites where values can be affected by ice breakup, snowmelt, and fall rains. Additional data should be collected to determine four-day average concentrations at key locations for comparison to CCC values.

- Tetra Tech (2013) and RTI (2007, 2010) compared baseline total metal concentrations to Alaska total recoverable criteria values and found a number of exceedences of the criteria. However, Alaska State water quality criteria require the use of *dissolved* metal concentrations for most metals, including copper, cadmium, lead, and zinc (State of Alaska, 2008). Dissolved metals are more bioavailable to aquatic biota, and measured dissolved metal concentrations should be compared to the dissolved criteria values. For many samples, particularly historical samples (1982–1994), the detection limit for metals is very close to the calculated water quality standard. It does not appear that these data were validated under strict quality assurance/quality control (QA/QC) guidelines. Uncertainty can be high when the measured concentration is so close to the detection limit, and a QA/QC analysis of such data often results in low concentrations being flagged as not detectable. Thus, it is difficult to determine the reliability of the data when concentrations are close to the detection limit.

- All hardness-dependent water quality criteria for surface water (and groundwater) were calculated using a hardness of 25 mg/L rather than the measured hardness, and hardness values were not measured in some of the older samples. If one uses actual hardness values for the groundwater samples, which are generally higher than 25 mg/L as $CaCO_3$, several of the concentrations noted as exceedences in groundwater samples (Table 1) do not actually exceed water quality criteria.

- For groundwater samples, well completion information for many of the historical monitoring wells cautions that the data should not be used for water quality evaluation because of well completion problems or issues (RTI, 2007, Table 5-3).

Alaska regulations require that if the hardness value is less than 25 mg/L as $CaCO_3$, actual measured values should be used (State of Alaska, 2008). The U.S. Environmental Protection Agency (EPA) also recommends that if hardness values are low (< 25 mg/L as $CaCO_3$), the hardness values used to calculate hardness-dependent water quality criteria should not be "capped" on the low end (at 25 mg/L) because of the uncertainties associated with limited toxicity data in that hardness range (U.S. EPA, 2002). Another reason noted by EPA is that "capping hardness at 25 mg/L without additional data or justification may result in criteria that provide less protection than that intended by EPA's Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and their Uses (EPA 822/R-85-100) or 'the Guidelines.'" EPA recommends the use of Water-Effects Ratios but, because of the large uncertainties associated with metal toxicity at low hardness values, site-specific toxicity testing using native fish species and metals or metal mixtures of concern would be preferable and more definitive.

Although the water quality tables and appendices presented in RTI (2007, 2010) and Tetra Tech (2013) imply that baseline surface water quality exceeds a number of relevant water quality standards or criteria, no evidence is presented that demonstrates or even suggests that existing surface water does not support all designated uses. Given the issues listed above, baseline surface water quality is not well characterized. More extensive baseline surface water quality investigations should be conducted, including an expanded temporal sampling effort that captures known hydrologic events and examines four-day average concentrations. If site-specific water quality criteria are being requested for constituents such as copper and zinc, especially in an area with known populations of anadromous salmon, site-specific fish toxicity testing should be seriously considered.

2.3.2 Geochemical testing and water quality mitigation measures

No information is provided on the potential changes in groundwater and surface water quality that could result from mining of the coal resource. Total dissolved solids, as well as trace metals and metalloids such as lead, manganese, nickel, chromium, cadmium, zinc, arsenic, and selenium, can increase as a result of the surface mining of coal (NRC, 1990). Although the sulfur content is described as "low" or "ultra-low" (RTI, 2007, 2010; Tetra Tech, 2013), no details on the sulfur content or the concentrations of metals or other potential contaminants associated with the coal and the mined materials are provided in the documents we reviewed.

The glacial material overlying the area is described as "highly mineralized" (Tetra Tech, 2013), yet no information about the metal content of the geologic units that will be managed at the site is provided in the water management plan or the baseline reports. Mining will include such activities as the creation of mine pits, grubbed areas, stripped areas, overburden piles, and the selective handling of alluvium, Glacial Drift, and other geologic materials. If some of these disturbed materials are metal-rich, the potential for releases of metals, in both dissolved and particulate forms, to streams and surface water during and after mining is a concern. The natural ability for site streams to protect aquatic biota from additional inputs of metals is limited, as evidenced by the very low hardness values discussed previously.

The sediment control ponds are proposed to be used for management of all water that contacts the mine facilities. Mitigation measures for management of particulates in the ponds are proposed (i.e., use of flocculants and coagulants, as evaluated in "jar tests"; Tetra Tech, 2013). However no information about the metal content of the geologic units that will be managed at the site is provided in the water management plan or the baseline reports.

In addition to the discharge of water from the sediment control ponds, surface waters surrounding the mine will receive pumped groundwater. The water management plan assumes that the groundwater pumped to access the coal and to depressurize the Sub Red 1 Sand unit will meet permit limits and applicable standards and will be discharged to surface water without treatment (Tetra Tech, 2013). Although previous water management plans had called for using infiltration basins, the most recent plan does not contain that mitigation measure. Instead, the pumped groundwater will be discharged directly to streams and possibly the Cook Inlet.

Even though the water management plan states that direct discharge from the sediment control ponds and pumped groundwater to surface water will be acceptable, the plan calls for managing the effluent using one or more approaches, including: mixing poor- and good-quality waters (e.g., waters from the Glacial Drift formation and the Sub Red 1 Sand unit, respectively); using an aeration system and filter to oxidize iron in groundwater; and pumping poor-quality water through a diffuser into Cook Inlet. Thus, the plan discusses multiple options for addressing contaminated water, after concluding that it will not generate any contaminated water. No information is presented on the effectiveness of these water management approaches in reducing dissolved or particulate pollutant levels. In addition, all documents assume that the measured baseline groundwater quality will be representative of groundwater quality during mining. Without conducting geochemical testing on the mined materials, the potential changes in water quality during mining cannot be evaluated.

More information is needed on the geochemical characteristics of the materials that are proposed to be mined and handled at the site, and how mining and handling of the geologic materials could affect water quality. Mineralogic and whole rock chemistry analysis of all mined materials (coal units, alluvium, Glacial Drift, and other geologic units) should be conducted. Short- and longer-term leach testing of all mined materials should also be conducted to evaluate the potential for oxidization of remnant sulfides and the generation of metal-rich leachate. The results of these geochemical tests will help inform predictions of operational and post-mining water quality. Currently, no active treatment (e.g., removal of dissolved metals) is proposed at any stage of the operation, yet not enough information is provided to evaluate whether such treatment could be needed. Although adaptive management could be used to address this issue during operation, the need for potentially expensive mitigation measures should be evaluated before mining begins so they can be incorporated into the plan of operations.

2.3.3 Water quality and implications for stream restoration

According to Tetra Tech (2013), mining would include handling and separate storage of top soil, alluvium, Glacial Drift, overburden, and interburden. The short section on the overview of mining also notes that the pit will be backfilled with interburden and overburden and covered with topsoil and that the surface water drainages will be re-established. The alluvial material is currently located "along active streams and floodplains" (RTI, 2007). No mention is made of whether the stored alluvium and Glacial Drift materials will be placed back in their original locations (as best as possible), or, as discussed in the previous comment, if the handling of these materials will release dissolved contaminants.

Groundwater quality reflects the interaction of infiltrated precipitation with the geologic material. The placement of the stored geologic materials after mining will affect surface water quality because groundwater quality is different in the alluvium and the Glacial Drift. For example, the Glacial Drift groundwater has lower hardness, alkalinity, calcium, magnesium, sodium, and potassium than alluvial groundwater (RTI, 2010, Tables 5-10 and 5-12). Hardness and alkalinity protect aquatic biota from the potential effects of toxic metals, and if Glacial Drift material is placed close to the stream corridor after mining, or mixed with alluvium, movement of infiltrated water through these materials could decrease even further the buffering capacity in streams. Additionally, Glacial Drift groundwater has higher concentrations of a number of metals, including aluminum, arsenic, cadmium, copper, iron, lead, manganese, mercury, nickel, silver, and zinc (RTI, 2010, Tables 5-10 and 5-12). Although most of the higher concentrations are total recoverable metals, dissolved copper, iron, manganese, and zinc concentrations are also higher in Glacial Drift groundwater than in alluvial groundwater.

3. Specific Comments Related to Hydrologic Conditions

This section contains a number of comments related to hydrologic aspects of the water management plan (Tetra Tech, 2013) and adds to our general comments in Section 2.1. In each example, quotations from the water management plan are followed by our comments.

p. 1: "The proposed Chuitna Coal Project is based on a nominal 1 billion metric ton low sulfur subbituminous coal reserve located within a 20,571-acre lease tract. The proposed area to be mined in the lease tract is approximately 5,000 acres and will yield a projected 300 million metric tons of coal."

Based on these numbers, this water management plan is for extraction of approximately one-third of the total coal resource and one-quarter of the total surface footprint. If there are plans for expanding beyond this initial one-third of the resource, the potential impacts of this expansion should be discussed.

p. 2: "A clay layer that is up to 30 feet thick occurs above the Sub Red 1 Sand unit which serves as an aquitard. For this reason, the Sub Red 1 Sand unit is confined, providing further hydrologic separation from the upper hydrogeologic units. It also exhibits a potentiometric surface that can reach into the Mineable Coal Sequence and above in some portions of the project area."

Although the clay layer beneath the Red 1 coal is "up to 30 feet thick," it is also "potentially missing" in some places (RTI, 2010). Given that the clay may be absent in some places, removing the Red 1 coal seam will in those locations effectively remove a confining unit from the Sub Red 1 aquifer, which could change the direction and amounts of groundwater flow and affect water management during and after mining. The plan is to depressurize this unit to prevent a large influx of water into the pit when the "cap" is removed. However, as described in the comments related to the groundwater modeling, the amount of water this pumping will yield seems highly uncertain.

In addition, there is no discussion of what will happen to the confined water from the Sub Red 1 Sand unit after mining. As described above, in locations where the confining clay is not present, removing the Red 1 coal will also remove the confining unit from the Sub Red 1 Sand aquifer. Once this confining unit has been removed and pumping is stopped after mining, water in the aquifer will eventually return to being overpressured and will flow into the pit backfill. This will alter shallow groundwater flow, groundwater-surface water interactions, and the overall functioning of the hydrologic system after mining. All of these impacts should be evaluated and discussed in the water management plan.

p. 5: "Gages C140 and C141, located in the upper reaches of 2003 and downstream of the majority of proposed mining disturbance, provided limited periods of overlap with C180, from which no consistent flow ratio relationship could be determined for individual months. It was therefore determined to use the record from C180, transposed to upstream locations by the use of drainage area ratios, for computation of the monthly water balance."

In effect, this means that the entire site water balance rests on a single streamflow record from station C180, and any errors in this streamflow record will propagate through the entire water balance. If there is no correlation between C140/C141 and C180, it does not seem reasonable to use C180 as a proxy for all of the gages. There needs to be some discussion of how this assumption could affect uncertainty regarding the water balance. As noted above, the report should also describe how water management actions will be adapted if key components of the water balance turn out to be different from expectations.

p. 5: "The record with the longest continuous term gage C180 in the 2003 basin shows a yield of up to 2.66 cubic feet per second/square mile (cfs/mi^2), but varied between 1.4 and 2.66 cfs/mi^2, depending on the period of continuous record examined (Table 2-1)."

The yield on station C180 varies by a factor of nearly two, depending on the period of record. It is not clear from the report whether this variability is due to natural variability in precipitation or perhaps to changes in the rating curve in this gage. In either case, this uncertainty in basin yield should be propagated through the remainder of the water balance calculations, because the entire water balance depends on the flow rate in this one gage.

p. 6: "These data show an annual evaporation of 13.48 inches per year after applying a standard pan evaporation coefficient of 0.7 to the average monthly values….However, based on additional review of studies conducted by Newman and Branton (1972) and Patric and Black (1968), and to account for a plant transpiration factor, it was determined that an additional 4 inches of evapotranspiration per year could reasonably occur at the project site. For this reason an annual evaporation rate of 17.5 inches per year was used in the water balance…"

The water management plan needs to justify this assumption; removing an additional 4 inches from the estimated evapotranspiration after applying a pan evaporation coefficient seems arbitrary. If this additional 4 inches of water did not go into evapotranspiration, it would go into streamflow or recharge and would represent an additional source of water that needs to be managed. As noted above, the report should describe how water management actions will be adapted if key components of the water balance such as this turn out to be different from expectations.

p. 6: "To achieve more accurate runoff rates for (future) disturbed areas in the water balance, July's evapotranspiration was partially reassigned to occur in May (50% allocation) and June (10% allocation). This was proposed because stream flow data were used to derive the precipitation estimation based on the water balance relationships described in Section 2.1 (e.g., precipitation = stream flow + evaporation + groundwater recharge). Some of the water that would normally be intercepted by vegetation and infiltrated into soil during spring runoff in May and June would be evaporated and transpired in the drier month of July…This shift will result in a more conservative design for the spring runoff event."

This needs to be clarified. If a “more conservative design” is intended to ensure that estimated peak runoff is not higher than expected, these model assumptions are counter-intuitive, and the design of sediment control ponds, for example, would be underprotective. For example, based on the water balance relationship described above, if evapotranspiration is increased in May and June, streamflow and/or recharge need to *decrease* in those months in order to maintain balance with the estimated precipitation. This assumption should therefore result in a *less* conservative design for spring runoff because there is effectively an extra 2 inches of modeled evapotranspiration being taken out of the system in May and 0.4 inches in June. Modeled peak flows would therefore be smaller than actual flows.

p. 6: “The calibrated model indicated that 27% of average precipitation recharges the Glacial Drift unit, of which 97.2% becomes stream base flow. The remaining 2.8% recharges the units below the Glacial Drift and does not contribute significantly to stream flow. The resulting base flow at gage C180 of 11.9 cfs, or 11.05 inches per year, was subtracted from the total measured stream flow to determine the surface runoff component for the water balance.”

There are a number of assumptions that go into these estimates, and many of the details are buried in the groundwater modeling and hydrology baseline reports (see detailed comments above). The uncertainties in all of these estimates and how these uncertainties feed into the water management plans need to be acknowledged.

Here and elsewhere, the level of precision reported in the water balance parameters gives a false sense of the degree of certainty in these estimates. Given the gross assumptions that are being made in the water balance calculations, it is very unlikely that the proponents can estimate recharge to the nearest 0.1%.

p. 7: The “wet” year estimate was 51.3 inches, or 106% of an average year, and the “dry” year estimate was 43.6 inches, or 90% of an average year.

See above comments. If the goal of these scenarios is to prepare for extreme events, the design events should reflect true extremes. The “wet” and “dry” years cited here are within the noise of average years, rather than reflecting true natural variability that would create far more extreme events than this.

p. 8: Runoff coefficients for undisturbed land (based on the pre-mining condition) were computed by dividing the surface runoff depth by the precipitation depth for each month. Resulting runoff coefficients varied by month (Table 2-4), ranging from 0.00 to 0.84, and averaging 0.44 for the “wet” year.

The general annual patterns of runoff coefficients make sense conceptually, i.e., relatively more runoff in spring and fall, and less runoff in the midsummer and winter when there is more evapotranspiration and storage in snowpack, respectively. However, based on Table 2-4 in the water management plan, there is no surface runoff at all in July. It is possible to envision a scenario in which runoff is zero in the wintertime when precipitation falls as snow, but it is difficult to imagine a scenario of zero runoff in midsummer, particularly on a landscape disturbed by mining. This is yet another example of a problem with their method of back-calculating precipitation from streamflow at C180 and evaporation at Matanuska.

p. 9: "Since the Glacial Drift, portions of the Mineable Coal Sequence, and the Sub Red 1 Sand will be dewatered and depressurized ahead of the mine pit, only small seepage volumes are expected from these units."

See detailed comments above on the groundwater modeling report. Based on our review of this report, the flow rates and volumes that are anticipated to come out of the Sub Red 1 Sand unit are not well constrained. As one example, in the groundwater modeling report, the confining unit is not modeled explicitly but is parameterized by assigning an extremely low vertical hydraulic conductivity to the Sub Red 1 Sand unit itself. This assumption will reduce the modeled recharge to the Sub Red 1 Sand, and could also influence the anticipated water yield from this unit.

p. 10: "At a minimum, diversion structures will be designed to convey the peak flow rates from the 2-year, 6-hour storm event occurring on the upstream watershed for ephemeral streams, and for the 10-year, 6-hour event for perennial or intermittent streams."

Again, this is not a very conservative design storm. If these estimates prove to be incorrect and the diversion channels are under-designed, the channels could erode during a peak flow event. The water management plan should describe the implications on water quality and/or mine infrastructure if this occurs. Furthermore, it is not clear that the 2-year or 10-year, 6-hour events can be well characterized based on the limited daily precipitation data at the site.

p. 17: "Pumped groundwater was assigned first to the 2002 and 2004 drainages, in an amount equal to or greater than the base flow depletions predicted by the groundwater model. Remaining available pumped groundwater was discharged to the 2003 drainage."

The 2002 and 2004 drainages would appear to be the least affected drainages based on the footprint of proposed mining, and therefore least likely to require augmentation. In order to maintain flows as close as possible to natural flows, the 2003 drainage would be in more need of augmentation than the other two drainages. The proponents should justify the decision to augment the 2002 and 2004 drainages before the 2003 drainage.

p. 18: "Because only small amounts of the 2002 and 2004 drainages are affected by mining, runoff values were computed for only the affected areas (diverted or changed land cover). Basin-wide impacts were then computed by subtraction."

Dewatering in the mined area is shown in the groundwater model report to lower groundwater levels beyond the boundaries of the mined areas. In addition to runoff changes, the report should also calculate and mitigate baseflow changes in these drainages due to mining.

p. 18: "The Mineable Coal Sequence and Sub Red 1 Sand unit are not hydrologically connected to the surface water system in the vicinity of mining, so pumping of these units results in a net increase in water yield above what is depleted by Glacial Drift pumping."

Figure 5.2-1 shows that the Sub Red 1 Sand unit is artesian near the confluence of tributary 200304 with 2003, so if there is a fracture or fault pathway for flow, it is possible that this confined aquifer feeds flow in these streams. If so, it seems that dewatering of this unit could potentially deplete baseflows in stream 2003. Alternatively, it is possible that strip mining and replacement of the bedrock with unconsolidated overburden could create a conduit for flow from the Sub Red 1 Sand unit that did not previously exist. It would be helpful to see additional support for the conclusion that mining will not influence baseflows.

p. 20: "It should also be noted that the February high flow targets for stations C141, C140 and C180 are quite low (6.6 cfs, 7.9 cfs and 17.3 cfs, respectively) in comparison to the surrounding months of January (20.4 cfs, 24.5 cfs and 53.7 cfs, respectively) and March (16.8 cfs, 20.1 cfs and 44.1 cfs, respectively) high flow targets."

This underscores a problem with the methodology used to calculate high-flow targets: because flows are based on historical data, natural variability in the short historical record is influencing the calculated high-flow targets. The proponents should consider developing a more rigorous treatment of the monthly flow statistics that would avoid this problem with month-to-month variability in flow targets.

p. 27: "Temperature data for groundwater in the Glacial Drift and Sub Red 1 Sand hydrogeologic units are provided in Tables 5-7 and 5-8 (RTI, 2007)…Surface water control ponds will be continuously monitored for temperature during the months when they are discharging."

According to baseline temperature data in the Hydrology Component Baseline Report (RTI, 2007), stream temperatures are 0–3°C from approximately November to April, and increase to 12–17°C in midsummer (Figure 2). In contrast, available data indicate that groundwater temperatures in both the Glacial Drift and Sub Red 1 Sand vary by only ~ 3–5° between April and July. Based on these data and the estimated pumping volumes from groundwater, it could be very difficult to maintain discharge temperatures that mimic the natural temperature variability present in these streams throughout the year, particularly in the stream reaches most immediately downstream from the discharge points. The plan should more explicitly calculate or model stream temperatures, and should also summarize the effects that changes in water temperature would have on aquatic biota if temperature criteria cannot be met.

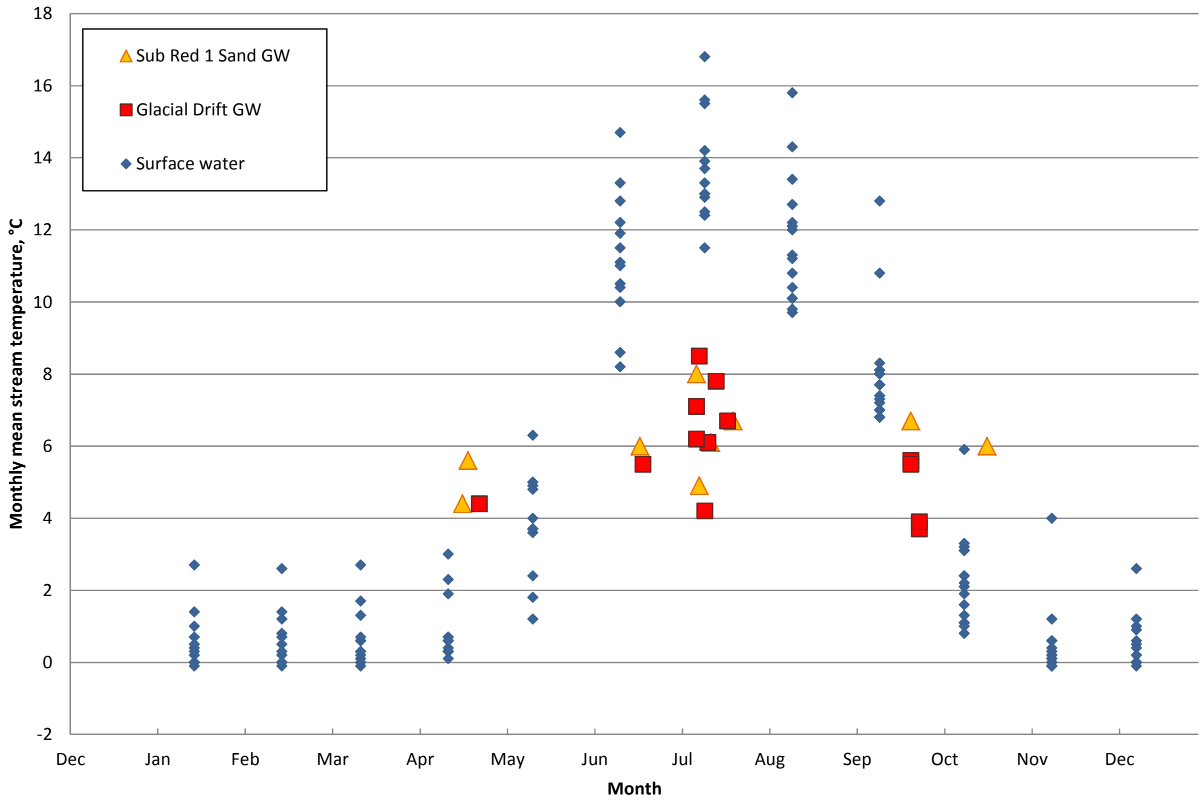

Figure 2. Monthly mean temperatures: Surface and groundwater.

Data source: RTI, 2007.

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